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Color Interpretation: a function of process & film.

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Introduction: When was the last time you went into a professional photography store and examined all the new color transparency products that are on the shelf? In recent years, Kodak as well as Fuji have released many new films such as Kodak's Underwater Ektachrome™ as well other transparency products such as Fuji Velvia™. There are currently many emulsions in the medium speed range(ISO 50/100). Which of these films is best suited for your photography and why.

I became interested in the inherent differences between emulsions while preparing a dental photography presentation for the Academy of Cosmetic Dentistry in 1988. As any photographer might, I needed information about the various films available, but the type of information I could put my hands on didn't help with predicting the visual results from the recording process. This particular group of dentists was interested in the way different emulsions rendered the dentition and gingival tissue. It was from this early work that I became familiar with the the recording characteristics of some films available at the time and have pursued more information as new products are continually released.

Why is it important to know about an emulsion's inherent recording differences anyway? Many photographers and others who make pictures use emulsions indiscriminately. Often a photographer selects a film based on the recommendation of a friend,colleague or publication such as this. The resulting photography may be entirely adequate pictures,but they may not be optimum for the recording task at hand.

When I began organizing this body of work, I was apprehensive about publishing new material on silver halide photography. The advances in electronic photography were so fast and the techniques are so powerful in their applications that there seemed to be a vacuum of people jumping into the digital world, myself included, at record numbers. However, advances in silver photography are paralleling the advances in electronic world. The result of this activity continues to provide more color accuracy to the professional photographer and to photography in general. There continues to be better integration of films working together with papers in the silver halide "image chain", the process of conceiving a picture, selecting a film and photographic strategy, photographing the subject and processing the film. For these reasons, I have though continued to publish work on silver films as many others do. In a recent article in Industrial Photography by Martin Hershenson, RPS, the author initiates thinking about trying new emulsions for obvious reasons. Like many of us, we have our "old favorites" and are reluctant to try new products, however I suspect you will be amazed.

The response to my original work, published in Tech Bits Number 2, 1992, has been very supportive. Since that original work only one year ago, many new films have been released such as the Kodak Lumiere family of Ektachrome Professional Films including Underwater Ektachrome[®]. Consequently, I have been curious about these new choices and I suspect more films will be on the horizon. Hence more knowledge of these choices and their possibilities and limitations is necessary to ensure the best result for a given application.

This article is not about taking a picture, but rather about making high quality, precise color photographic records of a subject on demand. One can make such photographs with educated choices about cameras, lenses and of course the best film for the situation at hand.

I find it fascinating to pick up a data sheet that discusses film products and read the copy that accompanies it. For example information about Fujichrome 50 Professional Film might read, "a good general purpose professional color slide film". This is obviously an understatement, but in many ways reflects the lack of complete data that may accompany a film today. Personally, I need something more specific and I suspect many of my contemporaries do as well. Knowing how a particular film performs and having the ability to previsualize the result from using that film, allows me to choose the most appropriate emulsion for a specific recording requirement.

When I am asked to photograph subtle changes that are occurring to the coloration in the fibrils of an iris, I want to be reasonably certain that the film will record the subject with high accuracy. It is no secret that some emulsions, specifically Kodachromes, are created with extended sensitivities. Consequently, subjects photographed using Kodachrome 64 Professional Film will be recorded differently than if that same subject were shot with Ektachrome 64 Professional Film. Generally speaking, Kodachrome Films and FujiChrome Films will render subjects warmer, but which film provides the most accurate representation of the subject provides some interesting issues for debate? What constitutes "better"?

Is better more saturation or greater fidelity? Is better warmer or cooler? It is important here to remember that photography is only a representation of reality and not reality by itself. In analyzing this question about which result is better, the answer might be "it depends". It depends on what is required, desired or preferred in a given situation. Knowledge about the way a film works, and actually the results provide some insights as to what will work better and why.

Achieving exact color can be difficult. In fact, it might be considered to be impossible by some because of the number of variables encountered from start to finish in the making of a color transparency. Considering the variables that influence the final results, one can understand why some experts are cynical. I am convinced that good color reproduction is possible with some hard work and reasonable awareness of the entire process and what factors can influence your results. Achieving good color quality is a fragile process.

In many cases, excellent color reproduction is almost crucial. For example, if color changes are occurring in skin as result of a prescribed drug treatment plan, can these changes be monitored accurately with photography? What knowledge, information and techniques must the photographer use to achieve accurate photographic documentation over time?

Emulsion Characteristics Before addressing the larger question of how to control, influence and select color transparency films, some fundamental characteristics of any photographic emulsion should be identified. Parts of these definitions may be referenced later in this article.

Films function the way they do because of the pre-determined characteristics that are built into the emulsion. These characteristics include:

- sensitivity(speed) - grain - resolution - saturation - spectral sensitivity - color balance - neutrality - contrast - exposure latitude - reciprocity

We will look at each of these characteristics briefly in an attempt to interrelate a films and how they function. It is difficult to analyze each characteristic alone as each directly and/or indirectly affects other film functions. A film's component parts are all interrelated in one way or another..

A film's sensitivity can be defined by how much energy is required to cause a response in the silver halides. The fewer the lumens required to stimulate the emulsion's silver salts, the higher the ISO of that film. The ISO of a transparency film is defined as:

$$ISO = 1/H_m \times 10 H_m = 2 \text{ point average of } 2.0 \text{ density above minimum density as well as } 0.2 \text{ above minimum density (Materials \& Processes of Photography, Stroebel 1985)}$$

Prior to the introduction of Kodak 's T grain' emulsions technology, the sensitivity of an emulsion was modified by changing the amount of silver halide or the size of the silver halide used for that film, however with tabular grain films, sensitivity is increased by increasing by flattening the grains to increase the actual surface area.

It is also useful to point out here that very strong relationships exist between some of these characteristics. For example, increasing film speed requires larger crystals or more silver halide to be used and so it can be said that higher ISO materials will have a larger or more pronounced grain pattern.

Graininess describes the the subjective impression of random unevenness observed using a grain focuser in enlargements or in other magnified images. Higher speed films typically display coarser grain while lower speed films exhibit virtually undetectable grain. Color transparency films are classified by a using a measurement or number referred to as diffuse RMS granularity value. Lower RMS numbers, such as 9 or 10 are very fine grain products, while numbers of 15 - 17 or higher and are coarser in grain str

ucture. For example, EPN Ektachrome 100 Professional film has a RMS granularity measure of 11 and is considered a fine grain emulsion.

Directly related to the size and frequency of the grain is the film's ability to resolve detail . When speaking about picture elements, a common mistake is to portray a product as very sharp. How sharp though? I recently rediscovered some of my early photomicrography that when I made them, I believed they were really sharp. When I re-examined them, they were quite soft by my current standards. Sharpness is a relative term and very subjective. Criteria changes from viewer to viewer and are contingent on experience and expectations. While resolution is defined as lines per millimeter reproduced on the film it is effected by contrast. Consequently, a film (EPN 100) that resolves 100 lines/mm at 1000:1, may only resolve 50 lines /mm at 1.6:1. These figures represent a film with said moderate or average resolution, while a film that resolves 125 lines/mm is said to have very high resolving power for slide films. Resolution is the product of inherent grain structure, film exposure, and photographic processing.

Color saturation refers to a film's ability to portray color with real richness or chroma. The finer the grain, the more compact the grain structure will be and consequently the higher the color saturation. Unlike the RMS granularity or ISO, saturation potentials of color films have no measurement system. Film descriptions usually contain only a reference to excellent color saturation if that information is provided at all.

Color balance is a function of the film's overall sensitivity to a particular light source which has a given color temperature, eg daylight or tungsten. Color transparency films can be balanced for either 3200K(tungsten) or 5500K(daylight) and for optimal results, the films should be exposed using light sources that match these aims closely. Light sources may vary from the nominal their color temperature and the photographer may need to use light balancing filters such as the Wratten 81 and 82 series.

Even subtle color temperature differences of light sources can affect color of a photograph. Tungsten halogen light sources are designed to deliver 3200K over their entire life. The color temperature of a tungsten lamp changes over the life of the lamp. These changes are manifested as color shifts in slides.

Similarly, electronic flashes and flash tubes vary widely in color output. This may be caused by the flash tube being coated or not coated with a filter to remove the UV radiation. Some diffusion materials may also influence the resulting color. It is important for critical work to test the diffusion material used over lights to ensure no changes to the color of the light as a result of what is used to diffuse it.

Spectral Sensitivity deals with the specific response of each film layer to a given range of wavelengths. The visible spectrum is comprised of wavelengths ranging from 400nm - 700nm. A color film has three emulsion, each with a different sensitivity. Because each film exhibits a balance of sensitivities, different films will record different hues and achieve neutrality differently.

FujiChrome, Kodachrome and Ektachrome films have different spectral responses to subjects. If generalizations are permissible, Kodachromes and Fujichromes render the world warmer with more red saturation than some Ektachromes Kodak 64 Professional film, EPR also as a generalization would render subjects cooler the Kodachrome 64 Professional.

Contrast describes the basic tonal separation between highlight and shadow in a subject as recorded by the film. In color transparency films, little or no contrast control is possible with slide films other than through the use different lighting strategies which change visual contrast of the image.

There is a slight difference in contrast when comparing the Ektachrome films to Kodachrome, the later being slightly more contrasty. The reality of the situation is, "contrast is reasonably fixed" in slide films. Push processing of Ektachrome 64T Professional Film was advocated for increasing contrast in photomicrography, however it has been my experiences, that the loss of color saturation and Dmax may be a result of this and consequently offset the subtle gain in contrast.

Color negative films have a wide exposure latitude that allows many of the point-and-shoot cameras to function as well as they do. Usable exposures can be achieved over a five stop spread,(- 2 normal, to + 2 stops). By comparison, color transparency films allow only a narrow range of exposures , typically +/- 1/2 stop from optimum, before critical detail is lost. The reason transparency films require such tight exposure control as compared to negative films lies in the inherent contrast of the film types. One can see from evaluating the characteristic curves, that slide films have a much greater contrast than negative films. For this reason, a small change in exposure on slide film produces a greater density change than the same exposure change on a negative film. This for some was a boon, while for others it was a curse. With any film, process controls determine the final density, contrast and color cast that a film will exhibit. Day-to-day and lab-to-lab fluctuations can radically change the final color.

One aspect of film choice often overlooked is the film's Processing. This is no surprise to this audience, however is still needs to mentioned as a characteristics specific to a film. The two processes utilized for current color slide films are E - 6 for Ektachromes, Fujichromes and others, or K - 14, the process used for Kodachrome films. Processor E - 6 allows user processing in about one hour. Process K -14 is available from a limited number of commercial laboratories. As many photographers/services are typically tight on deadlines, quick turnaround often mandates emulsion choice, however other choices should not be immediately discounted.

Exposures on the film is a product of intensity of the image forming light and the total time of exposure. This can be expressed by the equation

$$E = I \times T \text{ Exposure} = \text{Intensity} \times \text{Time}$$

From the relationship, one can see that an exposure of 1/60sec @ f/8 is equivalent to an exposure of 1/30 sec @ f/11. This relationship is known as the law of reciprocity.

There is, by virtue of this relationship, a range of time (controlled by shutter speed) and intensity (controlled by aperture) combinations that render the same exposure. In most situations the law holds; however, as exposures get very short (1/1000th sec or less) or very long (1 second or longer) the image produced may not have the predicted density. This is called the reciprocity law failure (RLF).

Reciprocity characteristics vary from film to film. Refer to the technical literature available for all professional transparency products to determine reciprocity information in very short or extended exposure situations. For example, EPT 160 at one second acts as though it were an ISO 100 product as contrasted to its 160 rating.

Other factors: Achieving faithful color reproduction is a challenge due to the many variables that can affect the final results. There are several other factors that can affect the fidelity of the final result. These include:

- Different batches/lot (emulsion number) of the same film type
- Contrast and/or direction of the light source
- Effect of the photofinishing on color and density
- Exposure and resultant saturation
- Professional and general picture taking films
- Age and storage conditions of the emulsion
- Latent image keeping
- Spectral "Blindness"

With all of these factors effecting the quality of the color reproduction process, it is easy to predict some difficulty in getting consistent color results over time. Each of these factors, can by itself, influence the deviation of the color result in varying degrees.

Often after the first generation original is created, post production color balancing may take place. Adding 5 cc green or removing the orange cast from a slide made of the incorrect color temperature is a simple activity with slide duplicating films. In fact, with electronic photography and digital imaging using programs such as Adobe Photo Shop, critical color is as easy as a "mouse" click away.

For the discriminating user of silver halide films though, post production activities, should be the last resort and not a planned on activity. There are several factors that can affect the fidelity of the final result.

Color emulsions are manufactured in very large quantities. Each time a new batch is created, it may show slightly different characteristics. To avoid variations, it is best to use the same emulsion where comparisons are to be made. Determine the batch and lot number by looking at the side of a box of professional film.

Photofinishing and its influences can greatly affect density and contrast. If a process is to be monitored over the course of time, all exposed films should be processed in the same run to avoid variances in chemical activity and its effects on color constancy.

The contrast and/or direction of the light source will effect the relative brightness between the highlight and the shadow produced at the subject. Contrasty (specular) light has a greater range of brightnesses while softer (diffuse) lighter sources will have less range between the highlight and shadow. Transparency films in general, work optimally approximately with an 80:1 brightness ratio between the usable highlight and shadow. This assumes a material with an approximate gamma of 1.8 -2.0.

The contrast of the light will also effect the value or brightness of color. Contrasty light will produce a different appearing color rendition than soft light because the white areas will be brighter and the shadows will be darker. Midtones in each lighting situation are likewise to be affected, yielding a different appearing contrast in each case.

In a prior illustration, the concept of contrast and its effect on color was demonstrated, but equally important to color quality is density as a product of exposure. Transparency films require very tight exposure control. The different densities produced as result of different exposures also effect the color saturation. Overexposed film consequently results in washed out or muted colors as contrasted to slightly underexposed film which results in greater saturated color. For this reason alone and the inability to predict with exact certainty the color saturation possible in any given circumstance, it is to bracket exposures in 1/3 stops increments over and under the predicted exposure.

One other comment about exposure and its potential role in color saturation. All contemporary films come in magazines that are DX coded. Because many of the current cameras read the DX coding, setting the ISO on the camera is almost a thing of the past. If you work with a DX-coded camera, make certain to read the packaged data sheet that comes with the professional films and override the DX coding when necessary.

Color transparency films are integral tri-pak films. Each of its sensitized emulsions, red, green and blue, have a slightly different responses as a function of the sensitization. As the emulsion ages, certain predictable changes occurs and each emulsion will lose sensitivity. The film will undergo a color shift. An expiration date is an indication of usability limits. Testing of the film can confirm at what point the material no longer delivers an acceptable image and should be discarded.

Transparency films may be acquired either as a professional or amateur picture taking films. Professional films are packaged close to aim for speed and color balance and are intended to be refrigerated to maintain that aim. Professionals also process their films soon after exposure. General picture taking films are released with slightly different aims to take into account the aging common in room temperature keeping over time before and after exposure and before processing.

Once the latent image has been captured, what happens next can influence the final result. The latent image is vulnerable to changes over time. These changes can be manifested as less effective exposure, an increased density of a color slide, or changes in color saturation. The image change or loss of latent image is contingent on storage conditions, the age of the film, and exposure to fumes from some chemicals.

The latent image is very stable for the most part. While general picture takers may obtain adequate results with processing years after the original exposure, professionals require more than merely adequate results. Some medical photographers never leave exposed films in camera for more than one week regardless of the number of exposures made.

For optimum results, the film should be processed as soon as possible after exposure. Refrigeration will minimize latent image changes.

Some subjects as beautiful as they are visually, just don't reproduce well on transparency film. Color slide film has three emulsion layers which ideally would have 100% sensitivity cross the three primary spectra, 400-500nm, 500-600nm, and 600-700nm. This does not happen as there are peak sensitivities and trough sensitivities. Consequently, some subject's colors may lie in regions that are not ideal for recording. These colors are then not recorded accurately. This results in slides which could include low saturation or false colors. Many examples of this occur, and so other emulsions should be considered if this is the case.

Predictable Film Relationships - Generally the higher the sensitivity, the more pronounced the grain pattern: the lower the ISO, the less pronounced the grain pattern. Tabular grain products may be an exception to this.

- The higher the sensitivity, the lower the resolution ;while the lower the sensitivity, the higher the resolution
- The higher the sensitivity, the lower the color saturation; while the lower the sensitivity, the higher the color saturation
- Higher contrast films may yield pictures that appear sharper, but in reality, they may contain less resolution
- Color slide films have more contrast than color negative films; however, there is no relationship between contrast and film speed in these films. Lower speed films may not necessarily be higher in contrast than higher speed films contrast than higher ISO materials
- Color negative films can have more latitude than color slide films, but there is no relationship between latitude and sensitivity
- Films with extended sensitivity may yield less accurate color reproduction

Color Interpretation: On the following pages are images that were produced under the tightest possible photographic controls. All emulsions were kept frozen prior to use and were re-frozen after exposure prior to processing. All films were processed simultaneously to insure each emulsion by itself demonstrated color interpretation and is not representing a color shift from the processing. In each series, the light source ,

camera, lens, and procedures were consistent in an attempt to allow the film itself to be the only difference that is presented as a final result.

On a Personal Note: In producing this project, it was my hope to provide other working professionals a better basis from which to select emulsions for their needs. By no means is any of this work meant to misrepresent any emulsion. However I am sure that in some ways, subconscious compromises must have occurred in producing this body of work. In many cases procedures were used that might not reflect traditional approaches, however data was the objective.

This project started out as a small curiosity on my part several years ago and blossomed quickly into over 100 rolls of exposed film & processing. I am greatly indebted and appreciative to the Scientific Imaging area of the Eastman Kodak Company, specifically Sally Robson, for moral and financial support for this research. To John Stone, former editor of Tech Bits magazine for his incredible skills with words and to Dr Richard Zakia, Professor Emeritus RIT, for his technical and emotional help with my research as a faculty member at the RIT School of Photographic Arts & Sciences.

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